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S. D. CASPER ETAL

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MULTI-SECTION ASYMMETRICAL COUPLER

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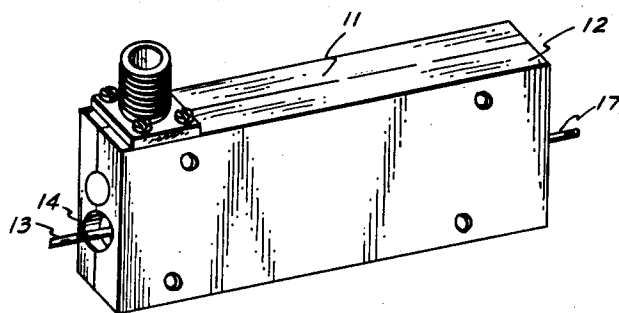


FIG. 1

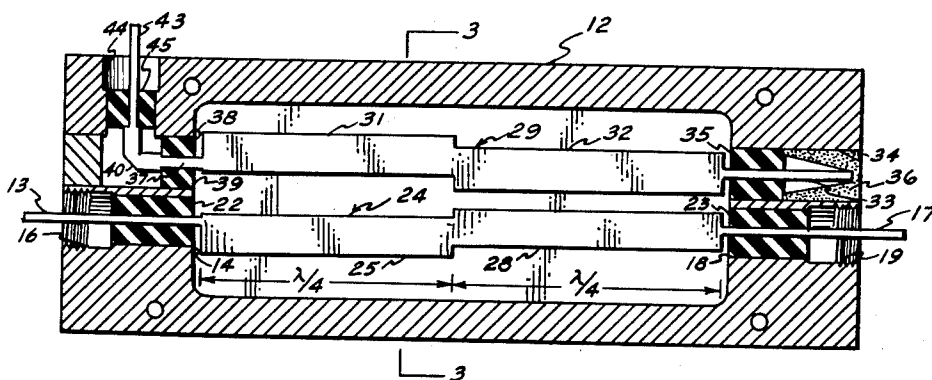


FIG. 2

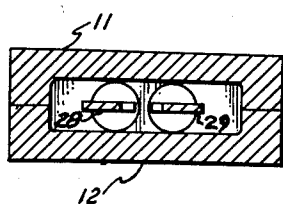


FIG. 3

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1

3,113,277

MULTI-SECTION ASYMMETRICAL COUPLER

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The present invention relates to microwave transmission lines and more particularly to directional couplers.

A directional coupler can be formed by coupling two strip transmission lines over a uniform coupling region that is one quarter wavelength long at the mid-band operating frequency. The wave induced in one line travels in an opposite direction from the inducing wave in the other line. In such a coupler, the amplitude of the induced wave remains substantially constant over a two to one frequency range, i.e., an operating frequency range where the upper frequency is twice the lower.

In another strip transmission line directional coupler, the coupling is effected over three consecutive regions, the coupling along the intermediate region being larger than that along the end regions. It has been found that if the coefficients of coupling along the end regions are related properly to the coefficient of coupling along the intermediate region, the amplitude of the induced wave remains almost constant over a five to one frequency range.

The design and theory of operation of the foregoing directional couplers are described in an article by J. K. Shimizu, entitled "Strip Line 3-Db Directional Couplers," pages 3-15, of the 1957 I.R.E. Wescon Convention Record, copyright 1957 by the Institute of Radio Engineers, Inc.

It is a principal object of the present invention to provide an improved directional coupler that has a substantially flat coupling response over a wide frequency range.

It is a further object to provide a broad band strip transmission line directional coupler that has a substantially flat coupling response over band widths covering up to a five to one frequency range, the coupler being shorter and more compact than previously known broad band directional couplers.

It is still a further object to provide a strip transmission line directional coupler having a minimum number of impedance discontinuities whose magnitudes are minimized.

It is yet another object to provide a directional coupler that is compact, extremely rugged, easy to construct, and is adapted to be used in coaxial transmission line circuits.

The foregoing and other objects and advantages of the present invention, which will become more clear from the drawings and the detailed description below, are attained by a strip transmission line directional coupler comprising two strip lines that are coupled together along two regions, each region being substantially one-quarter wavelength long at the mid-band operating frequency. The coefficient of coupling between the lines along one region is chosen relative to that along the other region so that a wave travelling along one line induces a wave along the other, whose amplitude remains substantially constant over a wide frequency range.

In the drawings, FIGURE 1 is an isometric view of the directional coupler of the present invention.

FIGURE 2 is a longitudinal sectional view of the coupler.

FIGURE 3 is a cross-sectional view of the coupler taken along the lines 3-3 of FIGURE 2.

Referring to FIGURE 1, 11 and 12 are two blocks of highly conductive metal which are screwed together to

2

form the outer casing of the directional coupler. Each of the parts 11 and 12 has a hollowed out region of U-shaped cross-section, shown more clearly in FIGURE 3.

The input end of the directional coupler is provided with a rod-like conductor 13 forming a female connector for receiving the inner conductor of an input coaxial transmission line, not shown. The conductor 13 is coaxially disposed within a bore 14 having a threaded region 16 forming a female connector for receiving the outer conductor of the input coaxial line.

The output end of the coupler is provided with a rod-like conductor 17 forming a female connector for receiving the inner conductor of an output coaxial line, not shown. The conductor 17 is coaxially disposed within a bore 18 having a threaded region 19 forming a female connector for receiving the outer conductor of the output coaxial line.

The bores 14 and 18 have highly conductive cylindrical surfaces that are coaxial. The conductors 13 and 17 are coaxially supported therein by dielectric beads 22 and 23, respectively. Thus, the coupler is provided with coaxial line connector devices for readily inserting it into a coaxial transmission line for detecting the magnitude of microwave energy reflections therein, for example.

A strip-like conductor 24 of highly conductive metal is rigidly supported between the ends of conductors 13 and 17. Conductor 24 has a rectangular cross-section, as is shown in FIGURE 3. The wide surfaces of the conductor 24 are parallel to the planes of the wide inner surfaces of the casing parts 11 and 12. The parts 11 and 12 constitute ground plane conductors of a primary strip transmission line whose strip-above-ground plane conductor is the strip-like conductor 24. Thus, the input and output connector devices for the coupler are coupled together by a strip transmission line. The input microwave impedance of this line preferably is equal to the characteristic impedance of the coaxial line in which the coupler is to be used.

The strip-like conductor 24 is divided into two sections 25 and 28, each having the same cross-sectional dimensions. The section 28 is coaxial with the input and output coaxial line connectors. The section 25 lies in the plane of section 28 with its axis displaced from the axis of section 28. The electrical length of each of sections 25 and 28 is substantially one-quarter of a strip transmission line wavelength at the mid-band operating frequency of the coupler.

A strip-like conductor of highly conductive metal 29, having two sections 31 and 32, is supported in the plane of conductor 24 in edge-to-edge relationship therewith as is shown in FIGURES 2 and 3. The conductor 29 has the same dimensions as conductor 24, and is supported within the casing 11, 12 so that the spacing between sections 28 and 32 is smaller than the spacing between the sections 25 and 31. The parts 11 and 12 of the coupler casing and the intermediate strip-like conductor 29 form a secondary strip-above-ground plane transmission line whose microwave impedance is the same as the primary transmission line.

The end of the section 32 of the secondary strip-above-ground plane transmission line is connected to the center conductor 33 of a terminating section of coaxial line whose outer conductor is the bore 34 in casing 11, 12. Conductor 33 is coaxially supported by a dielectric bead 35. A tapered microwave absorptive load 36 terminates the terminating section of coaxial lines 33, 34, for absorbing energy induced in the secondary strip transmission line by reflected energy along the primary strip transmission line.

The other end of the section 31 of the secondary strip

3

transmission line section is connected to an inner conductor 37 supported by a dielectric bead 38 within a coaxial conductive bore 39 in the casing 11, 12 to form an output connector for the secondary strip transmission line. A right angle bend 40 is provided for transferring energy with a minimum of reflections to an output coaxial line connector formed by a female inner conductor 43 supported within a female outer conductor 44 by a dielectric bead 45.

In operation of the directional coupler, microwave energy is supplied to the input coaxial line connector 13—14 in a TEM coaxial line mode. This energy is transferred to the primary strip transmission line 24, where it travels in a strip-above-ground plane transmission line mode toward the output coaxial line connector 17—18.

Both sections 31 and 32 of the conductor 29 are spaced close enough to conductor 24 to cause a wave to be induced in the secondary strip transmission line. This wave travels in a direction that is opposite from that of the inducing wave on the primary transmission line. The induced wave will not travel in the same direction as the inducing wave for reasons that are known in the art. Since the spacing between conductors 23 and 32 is smaller than the spacing between conductors 25 and 31, the components of the induced wave are primarily due to the coupling along the region of tighter coupling between conductors 23 and 32.

At the center frequency of operation, both coupling regions are one-quarter wavelength long. The components of the induced wave that are attributed to the coupling along the region between sections 25 and 31 are one hundred and eighty degrees out of phase with the components attributed to the other coupling region. Thus, the net amplitude of the induced wave that reaches the coaxial line connector 43, 44 is reduced.

At frequencies on either side of the above center frequency, it has been found that the net amplitude of the induced wave remains substantially constant over a five to one frequency range. The flatness of the response over this range is a function of the ratio of the coefficient of coupling along the region between sections 25 and 31 to the coefficient of coupling along the region between sections 23 and 32. This ratio is determined mathematically after deciding upon the design specifications of the coupler.

It should be readily apparent to those skilled in the art that the coupler is extremely easy to manufacture, is compact and rugged. No discontinuity exists along the ground plane conductors 11 and 12. Only one discontinuity exists along each of the primary and secondary strip-above-ground plane transmission lines. This is at the junction between the two quarter wavelength sections constituting each of strips 24 and 29. These particular discontinuities are not required to be very large for attaining the required ratio between the coefficients of coupling along the regions between the strip line transmission lines that produces the flattest coupling response. The coupling ratio, expressed in decibels, is approximately 6-db less than that required for prior art three sections cou-

4

plers having substantially the same performance characteristics.

While the invention has been described above having reference to one preferred embodiment and application thereof, it will be understood that it can take other forms and have other applications without departing from the scope of the invention. For example, other directional-coupler cross sections might be used such as are shown on page 11 of the above cited I.R.E. Wescon Convention Record. Also, the change in the coefficient of coupling from one of the quarter wavelength sections to the other can be accomplished in other ways which will be apparent to those skilled in the art. Therefore, the above description and drawings should not be regarded as limited except as defined in the following claims.

We claim:

1. A microwave strip line directional coupler comprising a ground plane conductor, a first strip-like conductor adjacent said ground plane conductor for providing a first strip transmission line, a second strip-like conductor adjacent said ground plane conductor for providing a second strip transmission line, each of said strip-like conductors being coupled to the other over its entire length, each of said transmission lines having a first end section and a second end section, each of said end sections being substantially one-quarter wavelength long at mid-band operating frequency for the coupler, the physical spacing of said end sections being such that the coefficient of coupling between said first end sections is greater than the coefficient of coupling between said second end sections, said end sections of said first line being substantially parallel to said end sections of said second line, and input and output coaxial line connectors terminating the end sections of said first strip transmission line.

2. The directional coupler of claim 1 wherein the axes of said coaxial line connectors are parallel to the axis of said first strip-like conductor.

3. The directional coupler of claim 1 wherein said coaxial line connectors include inner conductors, each of said inner conductors being an extension of its associated end section of said strip-like conductor.

4. The directional coupler of claim 1 wherein said coaxial connectors are coaxial with one another and wherein said end sections of one of said transmission lines are offset transversely from one another.

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